Waveform and discrete LiDAR effective LAI estimates: sensitivity analysis

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Abstract

Leaf area index (LAI), vegetation biomass and canopy height are very important structure parameters for many bio-geoscience applications, such as radiation transfer and carbon balance models. This study has investigated how average effective LAI derived from full-waveform and discrete LiDAR data changes depending on the size of the grid used, over a 150m by 80m area of orange orchard. The full-waveform data, acquired with RIEGL LMS-Q560, were decomposed and optimized with a trust-region-reflective algorithm using a custom decomposition procedure focused on extracting denser vegetation point clouds. Effective LAI LiDAR estimates were derived in two ways (1) from the probability of discrete pulses reaching the ground without being intercepted (discrete point method) and (2) from raw waveform canopy height profile processing adapted to small-footprint laser altimetry (waveform method). The validation of the LAI estimation methods was performed on a single White Cypress Pine Tree using fish-eye lens LAI estimates. This validation proved that waveform and point LiDAR LAI estimates were within 5% and 6% of fish eye lens estimates.
The LAI estimates for the orange orchard were derived for the whole site as well as in various decreasing grid cell sizes. The discrete method provided estimates 5-10% higher than waveform method, and this difference increased with the decreasing grid cell size. The only exceptions were the smallest grids (≤3m) for which the relation was opposite. This was due to the point method being limited by the density of points. Furthermore, percentage of vegetation cover in the test area was estimated based on aerial photography and used to derive an average single tree effective LAI depending on the grid cell size. These estimates were somewhat higher than those of a single orange tree processed individually but the single orange tree used for estimation was less dense than most of the trees in the study area. Consequently, the values of LAI for the whole site were simulated based on a set of assumed and increasing single orange tree LAI and known vegetation cover. This was done by predicting the LAI of the orange tree covered area and averaging this with the LAI of zero for the area of bare soil. These 'average' LAI values were compared to the LAI calculated for the whole site from summed probabilities of penetration for the orange tree area and ground area. As expected, with the increasing LAI of a single tree, the area LAI increased as well. However, as the LAI of single tree increased the difference between the 'average' LAI values and the 'whole area' LAI values increased significantly, from 5% for a single tree LAI of 0.2 to 267% for a single tree LAI of 5.0.